

Approaches for Resolving Dynamic IP Addressing

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ABSTRACT

Knowledge of the Internet Protocol (IP) address is essential for connection establishment in certain classes of synchronous distributed applications such as Internet telephony and video-conferencing systems. A problem of dynamic IP addressing arises when the connection to the Internet is through an Internet Service Provider since the IP address is dynamically allocated only at connection time.

This paper proposes and contrast a number of generic methods that can be classified as on-line and off-line methods for the resolution of dynamic IP addressing. On-line methods, which include the World-Wide-Web, exchange server and dynamic Domain Name System, are only effective when both the caller and recipient are logged onto the Internet. On the other hand, off-line methods, which include electronic mailing and directory service lookup, provide an additional means to allow the caller to leave messages when the recipient is not logged onto the Internet. Of these methods, the dynamic Domain Name System and directory service lookup appear best for resolving dynamic IP addressing respectively.

Introduction

In using the standard Internet Transmission Control Protocol/Internet Protocol (TCP/IP) suite (Comer, 1991), each host computer is identified by a unique IP address. This IP address is permanently fixed in the case of a direct connection to Internet. However, if the connection to Internet is through an Internet Service Provider (ISP), the IP address is dynamically allocated only upon connection and remains fixed during the duration of the session. The same IP address is subsequently reused and assigned to another new user. This dynamic allocation of IP addresses poses a problem for connection establishment in certain classes of synchronous distributed applications such as Internet telephony and video-conferencing systems. As such, there is a need to resolve this problem before a connection between users can take place.

In this paper, a number of methods are proposed to overcome this dynamic IP addressing problem. These can be classified as on-line and off-line methods. On-line methods are different from off-line methods in that the latter provides an option for the caller to make use of off-line communication means (such as electronic or voice mail) to leave a message in cases where the recipient is not connected to the Internet. In each case, both caller and recipient must obviously be connected to the Internet to allow real-time communication to take place between them.

On-Line Methods

In using an on-line method, a user upon connecting to the Internet will initiate a process or an application to register the current IP address to some form of server depository. After registration, this information can then be subsequently retrieved by other users for connection establishment. On-line methods which include the World-Wide-Web approach, exchange server, and dynamic Domain Name System are differentiated in the structure and role of the server depository and the mechanism used to register and retrieve IP addresses.

World-Wide-Web Approach

This approach uses the World-Wide-Web (WWW or Web) and its associated HyperText Transfer Protocol (HTTP)(WWW Consortium, 1993) servers for resolving IP addresses. HTTP connections over the Internet are implemented using the standard TCP/IP protocol. Each WWW document or resource has a unique address known as the Uniform Resource Locator (URL)(WWW Consortium, 1993). Users who are connected to the Internet and having access to HTTP servers would usually have home page directories assigned to them for putting up home pages on the Web. Information put up on such home page directories is accessible by anyone on the Internet. This in turn will allow a current user's IP address to be published and retrieved by other users through the knowledge of the current user's URL which is unique and fixed through the HTTP server. The URL is analogous to an electronic mail (email) address of an Internet user which is permanent and unique.

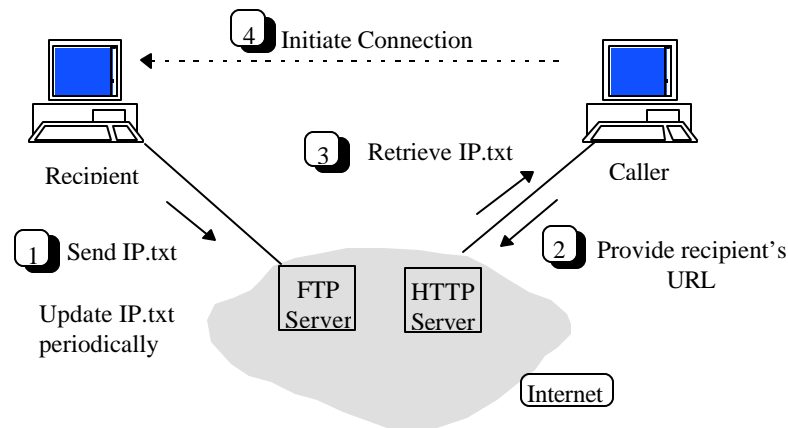


Figure 1. IP Address Resolution Using World-Wide-Web approach

The method used for IP address resolution using the WWW approach is shown in Figure 1. An agent (alternatively known as a process) on the user's host computer will write the user's information into a special file (say 'IP.txt') and use the File Transfer Protocol (ftp) to transfer the file to the user's home page directory. This information stored in the file is valid within a specified time-out period, and therefore, must be updated regularly while the application is on-line. This is necessary to overcome the problem of an abnormal disconnection (such as a power failure on the

host computer) which will result in out-dated and thus invalid data left in the file. For example, the IP address of the disconnected user may be re-assigned to another user who makes a connection to the Internet following the disconnection so that the IP address defined in the file is no longer valid. This regular update of information only applies to users with dynamic IP addresses since for the case of fixed IP addresses, the information in the file needs to be defined once only.

By knowing the URL of the recipient, the caller may retrieve the information directly from the IP.txt file and initiate a connection to the recipient by using the IP address defined in the file. When the user exits from the application, the agent will correspondingly remove the IP.txt file from the user home directory. This action although desirable is not critical due to the presence of the time-out mechanism which will automatically render this file invalid after being timed-out.

Exchange Server

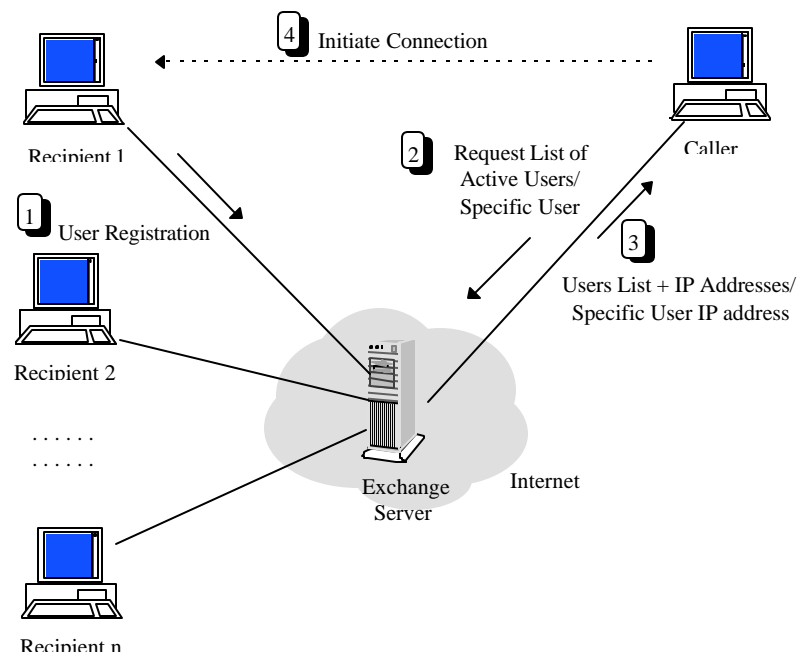


Figure 2. IP Address Resolution Using Exchange Server

An exchange server (ES) is a dedicated server to support an application for resolving IP addresses. An example would be a telephone exchange server for Internet telephony applications. The main responsibility of the ES is to maintain and manage the information of active registered users running the application. It acts as an exchange to facilitate finding and connecting users together as shown in Figure 2.

In order to support the possibility of a large number of active users at any one time, a database is usually used for storing users' information. Basic information stored by the exchange server include a unique user ID, user name and current IP address. This unique ID can be special ID defined by the server, an email address, an URL or any unique identifier defined by the application.

In using the ES, an agent must first register the user's own information with the exchange. When a connection request to a recipient is desired, a query is sent to the exchange. Two modes of queries can be supported by the ES. In the first case, the user knows the identity of the recipient and issues a specific query to the exchange to return the corresponding IP address of the recipient. In the second case, the user does not know the intended recipient and issues a general query to the exchange to return a list of active users and corresponding IP addresses and selects one for connection. The ES is basically modeled around the Internet Relay Chat (IRC) (Prospero, 1995) server, running software designed solely to help callers using a particular program find one another. When the user exits from the application, the agent will de-register the user from the ES.

In order to ensure that the list of registered users is current and up-to-date, the ES will periodically 'ping' (Mark, 1996) each registered user (*i.e.* user's IP port) to ensure that he or she is still on-line. This is necessary to cater for any abnormal termination of the application which is not being communicated to the ES. Furthermore, authentication during the 'ping' process is required to ensure that the 'correct' user is registered since the IP address could be already assigned to another user who is also registered with the ES. Users failing the 'ping' process will automatically be removed from the list of active users.

Variations to the basic ES architecture are possible. The agent can be replaced to accept direct user logins to the ES. Users are supplied with the same functionality to search and retrieve other users' information. Depending on the structure of the ES, information in the server can be partitioned and organized in some particular manner. Using the Internet telephony example, information may be organized by location, language, subject and interest so that users can register in various interest-group rooms. This will in turn support a chat-line facility to allow the user find and communicate with any other registered user in the ES. Anonymity can be supported by allowing users to use a nickname in place of their real name although a unique ID must still exist between users. Despite these variations, the basic method of using the ES to resolve dynamic IP addresses remains the same.

Dynamic Domain Name System

The concept of domain name was introduced in Internet to provide a mechanism to organize the large number of IP addresses into logical groups based on the organizations from which these systems belong. The Domain Name System (DNS) (Mockapetris, 1987), which consists of networks of resolvers and name servers, is an architecture built to support the use of domain name as an alternative to an IP address. Resolvers are used by Internet clients for retrieving information (the IP address in particular) pertaining to the domain name from name servers. Name servers are used to manage databases for storing domain name information.

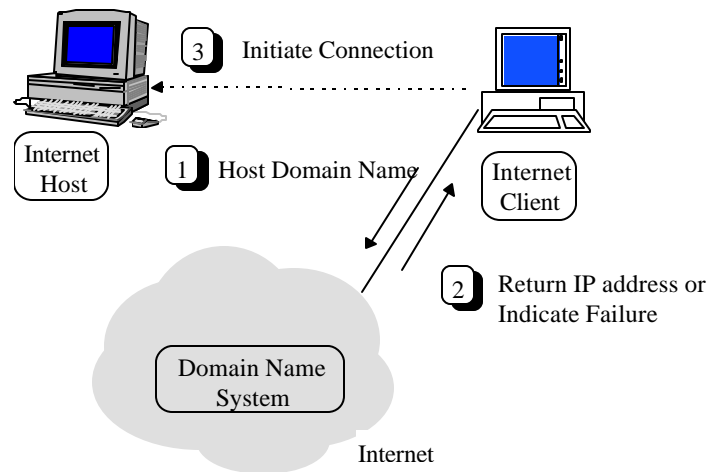


Figure 3 Mechanism of Domain Name System

Figure 3 shows the simple mechanism used for Internet connection when domain names are used in place of IP addresses. As most of the networks of Internet have access to at least one resolver, the use of domain name in place of IP address become very convenient and practical. This process eliminates the need to remember awkward IP addresses and the resolution from domain name to IP address is transparent to the user. Name servers manage two kinds of data. The first set of data are held in sets called zones; each zone is the complete database for a particular “pruned” subtree of the domain space. The second kind of data is cached data which is acquired by a local resolver. Such caching helps improve the performance of queries on domain name. Regular updates are required to keep an up-to-date information of the cached data. However, this implies that domain name changes will not be reflected immediately with the use of cached data. This does not pose much problems since the information stored in these name server databases are generally static and seldom change.

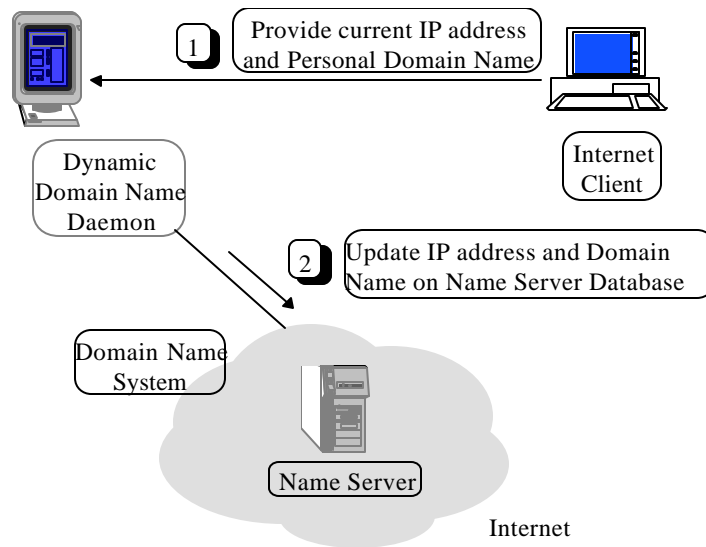


Figure 4 IP Address Resolution Using Dynamic Domain Name System

An extension to this existing DNS architecture can be made to allow dynamic update of domain names as shown in Figure 4. This extension, termed a dynamic Domain Name System, provides another approach for resolving dynamic IP addressing. In this system, all changes to the domain name information can be reflected in the domain name system immediately provided there is no caching done for that information. Every new connection to the Internet is communicated to a dynamic domain name daemon whose role is to update the user's information to the name server database. In doing so, it becomes possible to use a fixed domain name to identify an Internet host that may have a dynamic address. The normal DNS is subsequently used to resolve the IP address given a known domain name. This daemon together with the name server will be managed by an organization that has a registered domain in the DNS.

The fixed domain name is assigned to the user by the organization responsible for the domain. This name can take the form of *<user's domain name>. <registered domain>*. In the example 'user1.sas.ntu.edu.sg', 'user1' is the user's domain name and 'sas.ntu.ac.sg' is the registered domain. As in the previous exchange server approach, some form of 'ping' mechanism is used to maintain an up-to-date list of current users and cater for any abnormal disconnection.

Off-Line Methods

The off-line method basically functions similarly to the on-line method with the exception that it can still be used even though the recipient is not on-line at the time at the connection request. The method provides an answering machine facility to allow the user to leave a message for the recipient. Two methods, namely, electronic mail and directory service lookup, offer distinct approaches to resolve the problem of dynamic IP addressing.

Electronic Mail

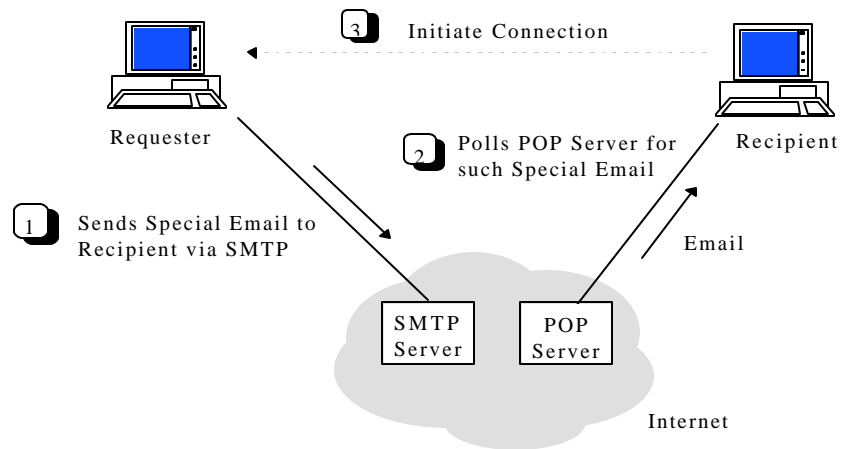


Figure 5. IP Address Resolution Using Electronic Mail Approach

This method utilizes the concept of fixed email addresses and uses electronic mailing as a means to resolve dynamic IP addressing as shown in Figure 5. In this design, the requester will only need to know the email address of the recipient. The Simple Mail Transport Protocol (SMTP) (Postel, 1982) is used to transfer a special email consisting of the requester's IP address and other information to a SMTP server machine which in turn uses SMTP to send the mail to the world at large. The Multipurpose Internet Mail Extension (MIME) (Borenstein, 1993) format which supports multimedia and multi-part mail has been chosen for mail representation. Mail from the world at large arrives on the recipient's Post Office Protocol (POP) (Rose, 1993) server where it awaits to be downloaded and processed.

At the recipient's end, an agent will poll the POP server periodically to check for such requests for connection. Upon receiving a connection request, the agent will retrieve and delete the call request from the POP server and inform the recipient of the request. If the request is accepted, the agent will act as the caller and initiate the connection through TCP/IP using the requester's IP addresses supplied in the email. The requester will subsequently authenticate the call and allow the connection to take place.

In this approach, a time-out period is defined in the special email to indicate the period of validity of the call request. As such systems are meant to be synchronous in nature, a connection request is terminated after being timed out. Thus, the agent will automatically discard all outdated requests. If desired, the agent can be optionally set to inform the recipient of the existence of such requests subsequently. In addition, the requester's end could also have an agent whose role is to monitor the same time-out period. Upon the expiry of the time-out period, the requester is correspondingly informed of the failure of the connection request and invited to submit a voice, video or electronic mail instead. This feature effectively emulates an answering machine for the requester to leave a mail for the recipient.

In addition to polling the POP server, the agent also polls the recipient's default mail inbox since there is a possibility that during the polling interval, the default email system could have been activated, downloaded and deleted all existing messages from the POP server to the default mail inbox. This results in a drawback in this approach since there is the need for the agent to cater for various default mail systems used by different users which will exhibit different characteristics and formats for mail storage and processing. In this instance, multiple agents will be required unless some form of standardization exists. However, this can be overcome if there is some way for the default mail system to identify and leave all such special email on the server for subsequent processing by the agent.

Directory Service Lookup

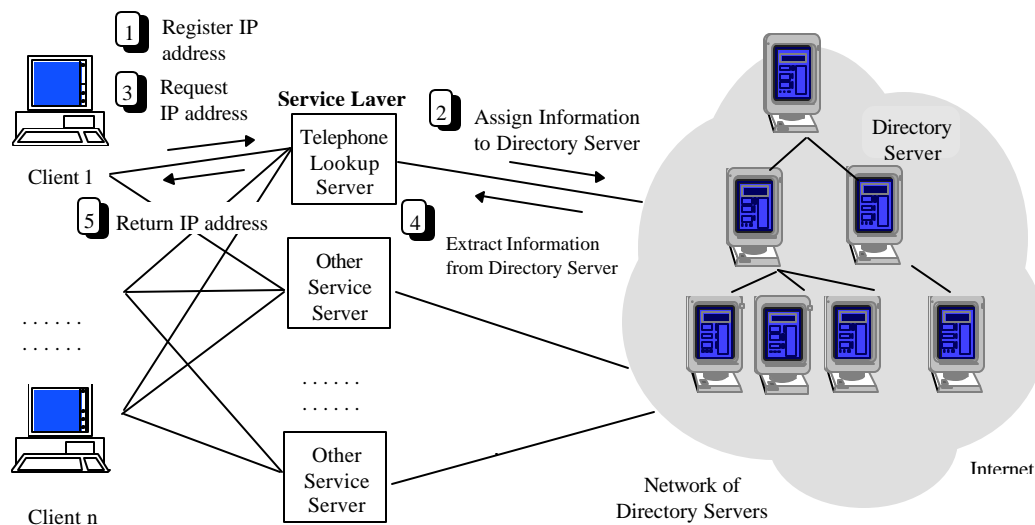


Figure 6. IP Address Resolution Using Directory Service Lookup

A complete profile of users' information can be stored in the Internet by using a network of databases known as Directory Servers. From this network of databases (or clusters), the information of any user on the Internet can be retrieved. Various servers with different purposes and support can be built as a service layer between Internet users (clients) and these directory service clusters as shown in Figure 6.

An example of a service server would be a telephone lookup server which functions similarly to a telephone exchange server. Additional functions and superior facilities can be added to these servers depending on the level of services offered and the amount of information stored in the directory servers. For example, the telephone lookup server may support a query requesting for a list of IP addresses of users of a particular age group with a particular set of interests and living within a certain area of the country.

The mode of usage of the service server is similar to the exchange server. Users with dynamic IP addresses will register this information (plus other temporary information that are set at connection

time) to the appropriate directory server. In order to make a connection to the recipient, a query for an IP address is sent to the service server which will in turn retrieve this information from the directory server and channel it back to the requester. An initiate connection request is subsequently issued by the caller to the recipient.

A possible architecture for these directory servers is use a geographic approach and organize them in clusters according to the country which they serve. Each cluster will consist of directory servers in a hierarchical manner to serve states, which in turn serve areas which serve users. This structure results in a hierarchical tree with the world as the root of the tree. Each sub-tree pertains to individual countries. The depth of the sub-tree will be dependent on the number of users which it serves. The architecture must be able to support the dynamic addition, removal and modification of directory servers and user information to the directory service as well as support simple and complex query and retrieval of information.

The motivation of using such a directory service is to provide a global White Pages service to facilitate global communications over computer networks in an efficient manner. Although the directory service lookup approach was originally conceived to handle IP addressing problems, it nonetheless has resulted in many similar ideas and characteristics with the existing X.500 directory service (CCITT, 1988). Since the focus of this paper is on techniques for resolving dynamic IP addressing, the differences between these directory services are of secondary importance and therefore would not be addressed.

Analysis and Comparison of Methods

All the proposed methods require some form of server depository for storing IP addresses which can be retrieved by the user. Depending on the method adopted, these servers are either stand-alone dedicated servers (dynamic DNS, directory service lookup), or dedicated servers (exchange servers) which are part of the application, or general servers (such as email or Web servers) which are an integral part of the Internet environment.

A number of factors have been used as a comparison between methods to gauge the efficiency and effectiveness to resolve dynamic IP addressing. These factors include:

Efficiency or Speed of Resolution. This factor refers to the time taken to resolve the IP address and allow a connection between users to take place. Users would obviously prefer the method that exhibits the shortest time.

Ease of Use and Acceptability. This factor relates to the ease-of-use of the method and the potential of users' buy-in. Users would prefer to use a simple and transparent method without the need to acquire new skills or change their current practices.

User Base Scope and Accessibility. This factor refers to the numbers of users that can be maintained by a particular method and the accessibility of this information by anyone on the Internet.

Set-Up Parameters Required. This factor pertains to the number and complexity of the set-up parameters that are required in order to use the method. Obviously the least number of parameters are desired.

Visibility of Available Users. This factor indicates the provision of the method to support a query for an active lists of users, or more specifically, to support a chat-line facility where the intended recipient is not identified beforehand.

Robustness and Resilience. This factor considers the robustness and resilience of the method and the circumstances in which it will fail to work. To some extent, this factor will depend on the resources under control. For instance, if a mail server serving the intended recipient is down, then it becomes impossible for the electronic mail method to proceed since the mail will not arrive at the server. In this case, the mail server is an external but necessary entity but is outside the control of the method.

Ease of Implementation and Associated Overheads. This factor examines the ease at which the method can be implemented and the overheads required to maintain it.

These factors have been used to rate each of the method under comparison. The results for the comparison of on-line and off-line methods are shown in Tables I and II respectively. These factors are ranked relative to each other. Whenever possible, quantitative data has been provided. However, absolute data may not be realizable due to the possible variations in implementing these methods. For example, the exchange server may be implemented as a query and retrieval model or an IRC model thereby resulting in significantly different speeds of IP address resolution. In such instances, a range of values are provided. In addition, average times are measured and used to cater for fluctuations in network conditions.

Table I. Comparison of On-Line Methods

	World-Wide-Web Approach	Exchange Server	Dynamic Domain Name System
Efficiency or Speed of Resolution (Average time, t(s))	slow ($3 < t < 300$)	medium ($1 < t < 180$)	fast ($1 < t < 4$)
Ease of Use and Acceptability	poor	moderate	good
User Base Scope and Accessibility	high	low	high
Set-Up Parameters Required (Number of Parameters)	moderate (3)	few (2)	few (2)
Visibility of Available Users	poor	good	poor
Robustness and Resilience	good	not bad	not bad
Ease of Implementation	easy	most difficult	difficult

In the on-line method, the dynamic DNS is the preferred method for IP address resolution. It is fast, easy-to-use and transparent to the user. Upon connection to the Internet, the dynamic domain name daemon will register the required information to the DNS system. Subsequently, the standard DNS will be used to resolve the address. Furthermore, this method is general and allows

any Internet application to make use of it directly without any additional overheads. The method is suitable for resolving the IP address of a known recipient. Such a service can be offered by an individual or organization who has a registered domain in the DNS. However, it is likely that it will be offered by ISPs as part of a standard service in future.

The exchange server is probably the first and most common method currently in use for resolving IP addresses. It has been adopted by many applications due to its simple concept and its ability to provide an early solution to the dynamic IP addressing problem. This approach has been widely adopted by almost all existing Internet telephony systems. Systems using this approach can either use a global server (e.g. FreeTel (FreeTel, 1996), CoolTalk 1.0 (Netscape, 1996)) or a set of distributed servers (e.g. Internet Phone 3.2 (IBM, 1996), Internet Connection Phone (VocalTec, 1996)) to implement the exchange. From the developers' point of view, the exchange allows them to keep track of their customer base, monitor volume and usage patterns, and provide support and services (e.g. advertisers) for their customers.

The World - Wide - Web approach uses a novel way to resolve dynamic IP addressing. The method requires the knowledge of the intended recipient's URL in order to be able to extract the desired information prior to connection. The method is not so elegant compared with the rest due to the overhead of having to update the information on the HTTP server to ensure that it is kept up-to-date. However, this method eliminates the need to have dedicated servers and uses only existing HTTP servers. In doing so, it makes use of standard Internet facilities and services which are likely to be more robust and reliable.

Table II. Comparison of Off-Line Methods

	Electronic Mail Approach	Directory Server Look-Up
Efficiency or Speed of Resolution (Average time, t(s))	slow ($10 < t < 3600$ (timeout))	fast ($1 < t < 30$)
Ease of Use and Acceptability	good	moderate
User Base Scope and Accessibility	low	high
Set-Up Parameters Required (Number of Parameters)	many (7)	few (2)
Visibility of Available Users	poor	good
Robustness and Resilience	good	not bad
Ease of Implementation	difficult	most difficult

Between the two off-line methods, the directory server lookup offers a better solution for dynamic IP addressing. This approach basically mirrors the exchange server approach in that it relies on the existence of servers, user registration and query support. Although it is arguable that the method is the same, the intended concept of using the directory service is different and should be viewed as one of the services provided by the directory service clusters. Like the dynamic DNS, the directory service is general and designed to service all Internet users and not any particular application. Depending on the services offered by the service layer, a total integrated communication system becomes possible to allow cross-media exchange of information. In addition, due to the flexibility and scope of information which it can support, it will invariably be able to exhibit superior functions over the exchange server.

The electronic mail approach uses a fixed email address concept to deliver a special email to the intended recipient who will in turn act as caller to establish the communication process. Although it is a workable solution, the main concern is the possible unacceptable time latency before communication can take place. The method relies on SMTP servers to transmit the mail to its destination. In some of our tests, it was found that the mail took longer than the time-out period to reach its destination, thereby immediately rendering the method inapplicable! Even when acceptable times are attained for mail transmission, there is a need to carefully define the polling time period to attain a compromise so that the CPU is not swamped with frequent periodic polling and yet able to deliver an acceptable level of service.

Conclusions

A number of methods have been proposed to overcome the dynamic IP addressing problem. On-line methods which include the World-Wide-Web approach, telephone exchange and dynamic Domain Name System can only be used when both caller and recipient are connected to the Internet. Off-line methods which include electronic mailing and Directory Service Lookup can still be used even though the recipient is not on-line. This is achieved by having a provision for an answering machine facility for the caller to leave a message for the recipient. These methods have been compared and rated according to a number of factors. It is concluded that the dynamic Domain Name System and Directory Server Lookup are the two best approaches for resolving dynamic IP addressing respectively.

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